WAR DEPARTMENT TECHNICAL MANUAL TM 11-379

TEST SET I-51
(CABLE REPAIRMAN'S)

WAR DEPARTMENT 23 SEPTEMBER 1943

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TM 11-379, War Department Technical Manual, Test Set I-51, is published for the information and guidance of all concerned.

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(For explanation of symbols, see FM 21-6)

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DESTRUCTION NOTICE

WHY —Don't let the enemy use or salvage this equipment for his benefit.

WHEN—Destroy when ordered by your commander.

HOW —1. Smash—Use sledges, axes, hand-axes, pick-axes, hammers, crowbars, heavy tools, etc.

2. Burn—Use gasoline, kerosene, oil, flame-throwers, incendiary grenades, etc.

3. Explosives—Use firearms, grenades, TNT, etc.

4. Disposal—Bury in slit trenches, fox-holes, other holes. Throw in streams. Scatter.

5. USE ANYTHING IMMEDIATELY AVAILABLE FOR DESTRUCTION OF THIS EQUIPMENT.

WHAT—1. Smash—Tone unit, exploring coil, and receiver.

2. Burn—Tone unit, receiver cord, and manuals.

3. Bury or Scatter—Any or all of the above pieces after breaking.

DESTROY EVERYTHING

SAFETY NOTICE

The voltage and current from Test Set I-51 are not dangerous to life, but can produce an unpleasant shock. Don't touch the output terminals or wires connected to them when the test set is in operation.

Don't listen to the tone through a receiver connected to the output terminals or wires connected to them because the full volume may hurt the ears.

Follow the precautions given in Section II, paragraph 3, in disconnecting equipment from cable pairs to which the tone is to be connected.

SECTION I

DESCRIPTION

	PARAGRAPH
General	1
Component parts	2

1. General

a. Purpose.

Test Set I-51 is designed to be used for locating faults in short lengths of non-loaded telephone cable. The test set may be used in locating grounds, shorts, crosses, split pairs, and wet spots; it is not intended for use in locating opens.

b. Application.

In use, tone is applied to the faulty circuit, and the magnetic field set up around the conductors of this circuit is detected by means of an exploring coil in series with a telephone receiver. The exploring coil is held against the cable and moved along between the tone source and the fault, the exact location of the fault being indicated by a marked reduction in volume or the complete absence of tone in the receiver when the exploring coil is moved past the fault.

2. Component Parts

a. General.

Test Set I-51, shown in Figure 1, consists of a tone unit, an exploring coil, a telephone receiver and cord, and a plug for connecting the receiver cord to the exploring coil. The test set is housed in a wooden case which is provided with an adjustable length strap to permit the set to be carried by hand or suspended from the shoulder. The case is approximately 12 inches long by $6\frac{1}{2}$ inches wide by $10\frac{1}{2}$ inches high. The inside of the case is divided into three compartments, one for housing the tone unit, one for the batteries, and one for storing the exploring coil, cord, plug, and receiver. The total weight of the test set including batteries is approximately 20 pounds.

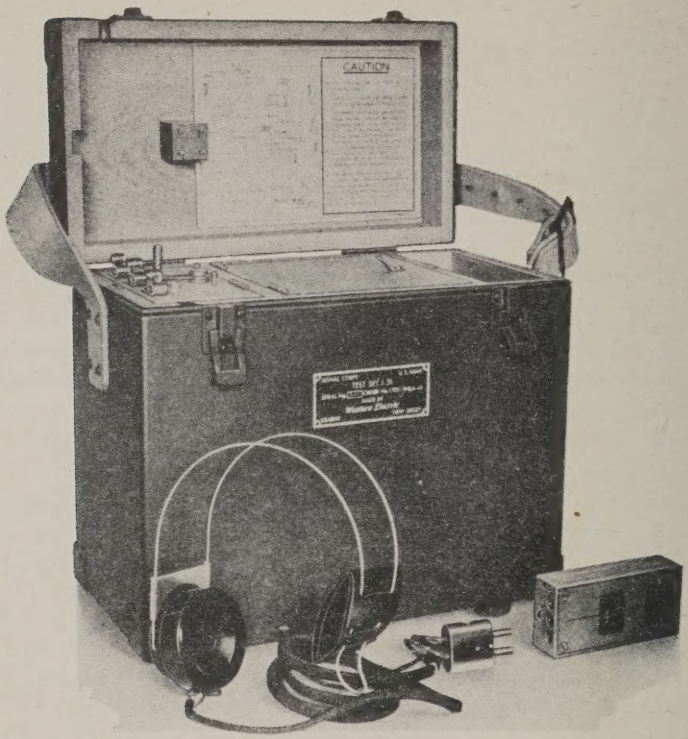


FIGURE 1.—*Test Set I-51.*

b. Tone unit.

The tone unit is designed to furnish tone supply of either a steady or interrupted type to the circuit under test. The tone unit, shown removed from the case in Figure 2, consists of an induction coil, a vibrator, an electromagnetic interrupter, a capacitor, two resistances, a single pole three-position switch, and three output terminals. The tone unit is operated by a six-volt battery comprised of four Batteries BA-23 (1½ volts) connected in series. The tone unit generates an alternating voltage in the audio-frequency range, the major part of the energy being in the 800- to 1400-cycle

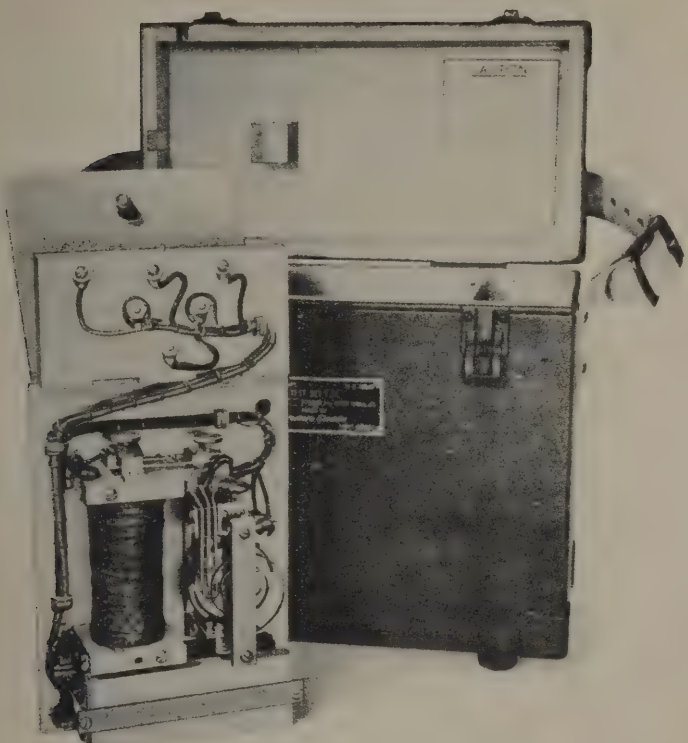


FIGURE 2.—*Tone Unit Removed from Case.*

range. A low impedance output is provided by terminals 3 and 4 of the tone unit and a high impedance output by terminals 3 and 5. The electromagnetic interrupter permits obtaining interrupted tone when desired. An interrupted tone is supplied when the switch is on position 1 and a continuous tone is supplied when the switch is on position 2.

c. Exploring coil.

The exploring coil, approximately 4 inches by 2 inches by 1⅛ inches, consists of a laminated core, two coil windings,

and a capacitor, enclosed in a metal case. The coil windings and the capacitor are interconnected and terminated in jacks located at one end of the exploring coil. The jacks are arranged so that the 2-prong plug attached to the end of the receiver cord can be inserted in either of two positions (marked G and S on the case of the exploring coil), as the occasion demands, depending upon the conditions of test.

SECTION II

INSTALLATION AND OPERATION (Location of Faults)

	PARAGRAPH
Precautions	3
Tests	4
Location of grounds	5
Location of shorts	6
Location of crosses	7
Location of split pairs	8
Location of wet spots	9

REMEMBER THESE POINTS

1. Look for the simple causes of trouble first.
2. Keep clean and free from grease or oil and dust.
3. Don't let moisture enter the cable. It impairs insulation and lowers resistance. Keep the inside of your unit dry.
4. Don't touch the output terminals or wires connected to them when the test set is in operation.
5. Before connecting the tone unit to a working cable, check the pair under test to avoid wrong connections.
6. Don't listen to the tone with headphones connected to the output terminals, or wires connected to them. The volume may hurt your ears.
7. If the vibrator stops while being adjusted, open the switch immediately, as the battery circuit is closed through very low resistance. If this isn't done, your battery will run down rapidly.
8. To more easily locate short circuits and split pairs, use an amplifier with the exploring coil.
9. This unit is easy to use. Keep it in shape. Have this book handy. It may help you out of a tough spot.

3. Precautions

Before connecting the tone unit to a working cable, carefully check the pair under test to avoid wrong connections. Disconnect the pairs under test from the switchboard by removing the heat coils, or, in the case of toll cable, by opening the pairs at the frame or testboard. If the pairs under test are connected to switchboards at both ends, as are trunk, toll, and P.B.X. lines, disconnect the pairs from both switchboards. If these precautions are not followed, the switchboard attendant may receive a signal and answer the circuit to which the tone unit is connected, because of hearing the tone from the tone unit in the receiver.

4. Tests

a. Test Set I-51 may be used for locating grounds, shorts, crosses, split pairs, and wet spots in cables. It is not intended for use in locating opens.

b. A ground is an electrical contact between a conductor and the sheath. This electrical contact may be due to actual mechanical contact between the wire and the sheath, or it may be due to moisture which has entered the cable in some way and has impaired the insulation to such an extent that it lowers resistance.

c. A short is a connection between two conductors of the same pair.

d. A cross is a connection between two conductors of different pairs.

e. A split pair results from a splicing error in which the two conductors of a pair in one cable section are connected one to a conductor of one pair and the other to a conductor of a different pair in the adjoining section. This fault is illustrated in Figures 9 and 10.

f. A wet spot is a combination of grounds, shorts, and crosses due to moisture penetrating through an opening, such as a crack or other hole in the sheath.

g. An open is a break in a conductor.

5. Location of Grounds

a. Connect the tone unit as shown in Figure 3, and operate the switch to position 1. Insert the plug in the jacks marked

G and hold the exploring coil on the telephone cable in the position shown in Figure 4. Then move the exploring coil

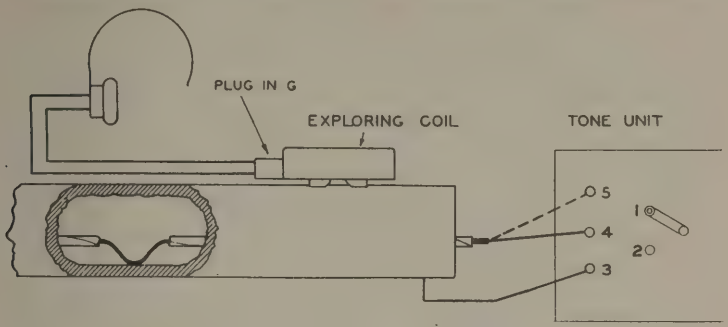


FIGURE 3.—*Connections for Locating Grounds.*

along the cable sheath until the tone, as heard in the telephone receiver, disappears or suddenly decreases in volume, thus indicating the exact point of the fault. In high resistance

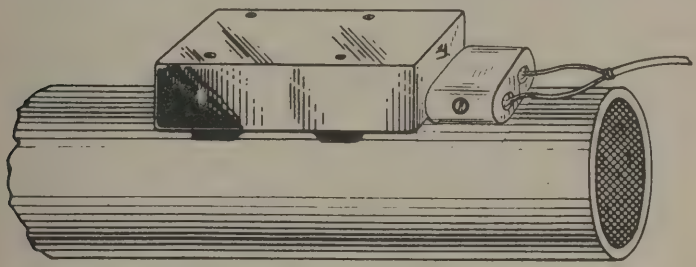


FIGURE 4.—*Position of Exploring Coil for Locating Grounds.*

faults the tone will not disappear entirely when the fault has been passed. This is due to the carry-over effect of the capacitance of the wire beyond the fault. In some cases the change in volume of tone is so slight that an absolute location is uncertain. In such cases, before opening the cable, connect the tone unit first to one end of the cable and then to the other, checking one location against the other. When testing aerial cable, hold the exploring coil on the underside of the cable in order to minimize interference due to current flowing in the supporting strand.

b. A greater volume of tone can be obtained if the exploring coil is held on the cable in the position shown in Figure 8, with the plug in the jacks marked S. However, when the exploring coil is held in this position, sheath currents will affect the voltage induced in the coil. For this reason, the exploring coil should be used in this manner for locating a ground only when the cable is reasonably free of sheath currents; otherwise the induced tone due to the stray currents in the sheath may reduce the effectiveness of the tone from the tone unit.

6. Location of Shorts

Connect the tone unit as shown in Figure 5, and operate the switch to position 2. Insert the plug in the jack marked S and hold the exploring coil on the cable in the position shown in Figure 4. For proper understanding of the method of locat-

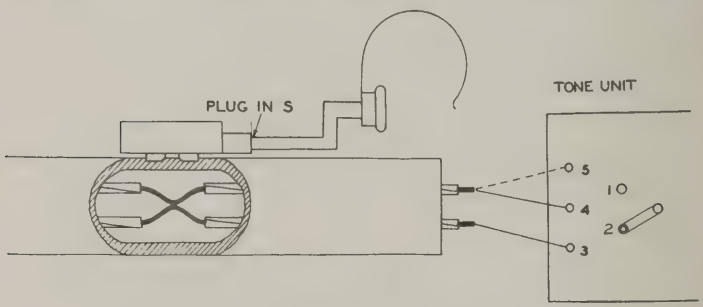


FIGURE 5.—*Connections for Locating Shorts.*

ing short circuits with the exploring coil, it is necessary to consider the effect, on the exploring coil, of currents flowing in a short-circuited pair. When current is flowing in a short-circuited pair, as shown in Figure 6, a maximum tone will be heard when the exploring coil is held as shown in "A" with the pole pieces centered over two adjacent loops of the wires in the pair. If the exploring coil is moved along the cable to the position "B", in which the pole pieces are centered over the crossover points in the short-circuited pair, no tone will be heard. At intermediate points the tone will be less than at "A", and more than at "B". If the exploring coil is moved

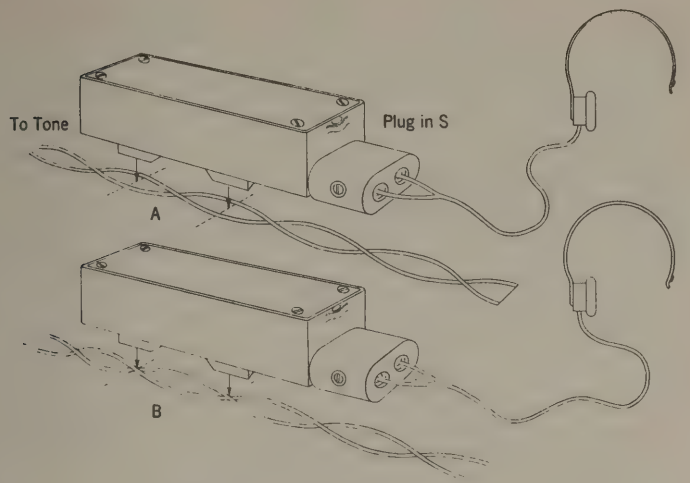


FIGURE 6.—*The Short-circuit Effect.*

steadily along the cable over the short-circuited pair, the volume of tone heard in the receiver will alternately rise and fall; this is called *the short-circuit effect*. To locate a short-circuit, move the exploring coil along the cable from the source of tone toward the fault. The short-circuit effect will be heard up to the fault. Beyond the fault, no tone will be heard or the volume will be greatly reduced.

7. Location of Crosses

Connect the tone unit as shown in Figure 7 and operate the switch to position 1. Insert the plug in the jack marked S and hold the exploring coil on the cable in the position shown in Figure 8. When current is flowing through two crossed wires it will be impossible to detect the short-circuit effect described above, but the tone heard in the receiver will be approximately constant between the tone source and the fault. Beyond the fault, no tone will be heard, or there will be a marked reduction in its volume. The steady volume tone heard in connection with crossed wires is called *the crossed-wires effect.*

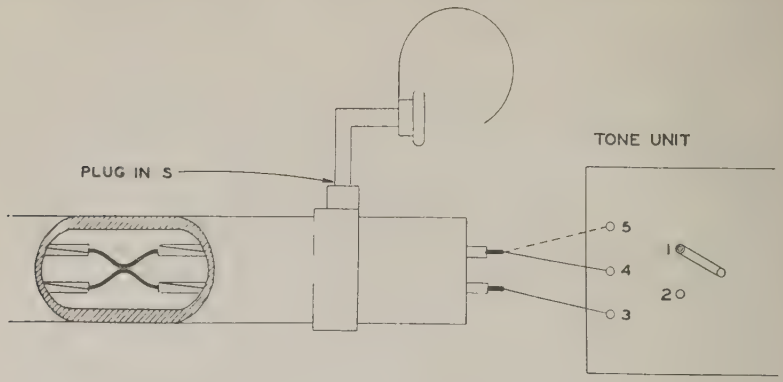


FIGURE 7.—*Connections for Locating Crosses.*

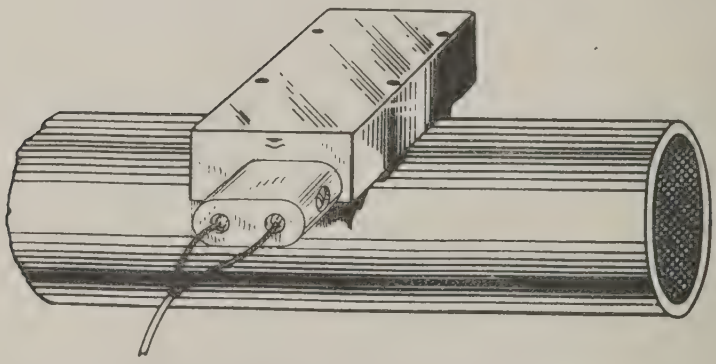


FIGURE 8.—*Position of Exploring Coil for Locating Crosses.*

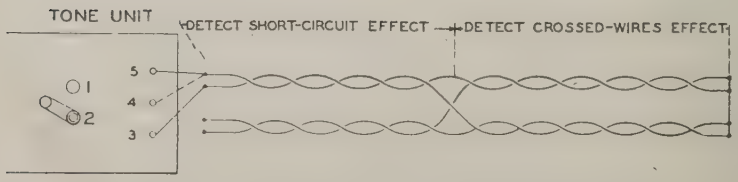


FIGURE 9.—*Connections for Locating Split Pairs.*

8. Location of Split Pairs

Strap all four wires of the two pairs together at the far end of the cable, connect the tone unit as shown in Figure 9, and operate the switch to position 2. Insert the plug in the S jack of the exploring coil. As indicated in Figure 9, the crossed-wires effect (par. 7) will be obtained up to the point of fault and thereafter the short-circuit effect (par. 6) will be obtained. If the tone unit is connected as shown in Fig-

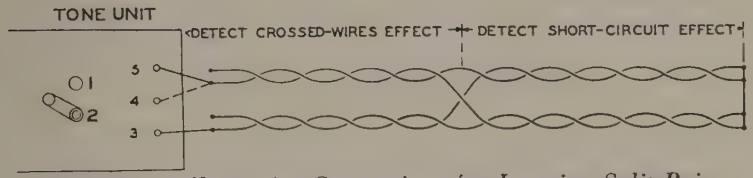


FIGURE 10.—*Alternative Connections for Locating Split Pairs.*

ure 10, the short-circuit effect will be obtained up to the point of fault and the crossed-wires effect thereafter.

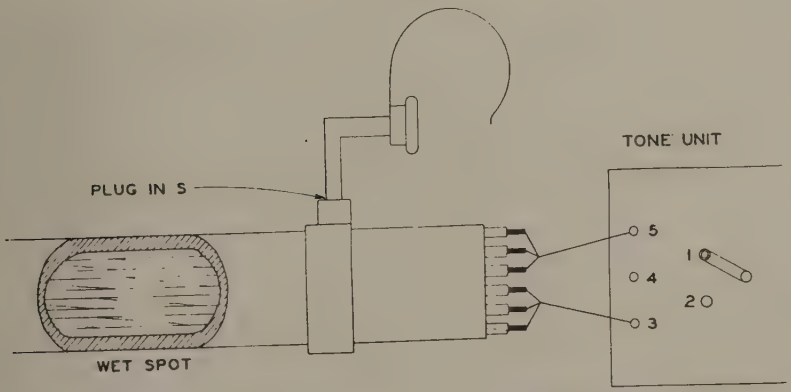


FIGURE 11.—*Connections for Locating Wet Spots.*

9. Location of Wet Spots

To locate wet spots in cable, select a number of pairs of wires having the lowest insulation resistance; divide these pairs into two equal groups, bunch each group, and connect the tone unit as shown in Figure 11. In locating wet spots, it will generally be desirable to use terminals 3 and 5 of the

tone unit, since the resistance through a wet spot is relatively high. Operate the tone unit switch to position 1. Insert the plug in the jack marked S and hold the exploring coil on the cable in the position shown in Figure 8. No tone should be heard in the receiver beyond the location of the fault. Another method for making the tests for wet spots is to connect several pairs to one of the tone unit terminals which are to be used and the cable sheath to the other and then proceed as in the location of grounds, described in paragraph 5.

SECTION III

FUNCTIONING OF PARTS

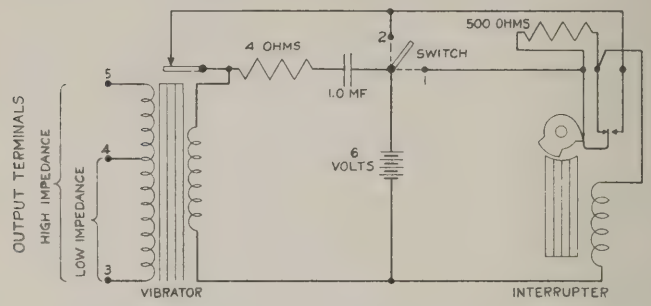
	PARAGRAPH
Principle of operation	10
Functioning of tone unit	11
Functioning of exploring coil	12

10. Principle of Operation

The tone unit (source of alternating current) is connected between the faulty wire under test and the cable sheath, or some other wire in order to form a complete electrical circuit, thus permitting current to flow from the source through the faulty wire, the fault itself, and back by the return path to the source. This flow of current will set up an alternating electromagnetic field around the conductors carrying the current. When the exploring coil, in series with the receiver, is held close to the cable in such a way that its windings will be cut by this alternating electromagnetic field, a current will be produced in the windings of the exploring coil and a tone will be heard in the receiver. When the exploring coil is carried beyond the fault, the tone will either cease or decrease in volume, thus indicating the exact location of the fault. The design of the exploring coil is such that, when held parallel to the telephone cable, it is neutral to sheath currents and such currents will produce no tone in the telephone receiver. The magnitude of the induction in the exploring coil, and the resulting tone in the receiver will depend upon the resistance through which the tone current must pass and the distance between the conductor in trouble and the cable sheath. For instance, if the fault resistance is high, the tone current and resultant induction will be low. Likewise, a high conductor resistance (long length of line between the fault and the point of application of the tone) will tend to reduce the tone and resultant induction. Also, when the conductor in trouble is located near the center of a large cable, the induction will not be so great as when the conductor is located near the sheath.

11. Functioning of Tone Unit

a. The schematic circuit of the tone unit is shown in Figure 12. The tone unit consists essentially of a vibrator for



Switch on 1: vibrator operates periodically
Switch on 2: vibrator operates continuously

FIGURE 12.—*Tone Unit Schematic Diagram.*

interrupting the current through the primary of an induction coil. This induces a voltage in the secondary of the induction coil, which is impressed on the faulty circuit. The secondary windings of the induction coil are connected to the output terminals 3, 4, and 5 in such a manner as to provide a low impedance output between terminals 3 and 4 and a high impedance output between terminals 3 and 5. When the fault is of low resistance (100 ohms or less), use the tone from the low impedance terminals 3 and 4. When the fault is of high resistance (greater than 100 ohms), use the tone from the high impedance terminals 3 and 5. The resistance of the fault may not always be known. On this account it is generally advisable to try both pairs of terminals, 3 and 4, and 3 and 5. The pair of terminals which gives the greater volume of tone in the receiver, when the exploring coil is held at some convenient point on the cable, is the proper pair to use for locating the fault in question.

b. The tone unit is provided with an electromagnetic interrupter for alternately closing and opening the battery circuit. This permits the alternating current to be applied at

regular intervals and enables the tester to distinguish between the tone produced by the tone unit and tones from other sources and extraneous noises. When the switch is operated to position 1, the vibrator operates periodically and an interrupted tone is supplied by the tone unit. When the switch is operated to position 2, the vibrator operates continuously and a continuous tone is supplied by the tone unit. For locating grounds, crosses, and wet spots, the interrupted tone is preferable; for locating shorts and split pairs, the continuous tone is generally more satisfactory.

12. Functioning of Exploring Coil

The schematic circuit of the exploring coil is shown in Figure 13. The exploring coil consists of two coil windings

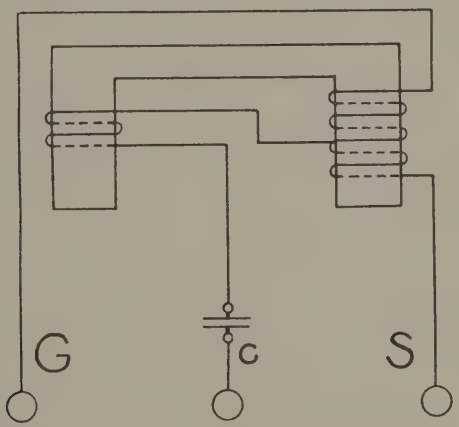


FIGURE 13.—*Exploring Coil Schematic Diagram.*

(mounted on a laminated core) and a capacitor, interconnected and terminated as indicated, and enclosed in a metal case. The two pole faces of the core protrude through the cover of the case and the terminal jacks are accessible at one end of the case. The jacks are arranged so that the 2-prong plug on the receiver cord can be inserted in either of two positions, depending upon the conditions of test and the type

of fault to be located. These two positions are marked G and S on the cover of the exploring coil and are indicated schematically in Figure 13. The exploring coil will be found, generally, to perform more satisfactorily with the plug in the G jack when locating a ground, and with the plug in the S jack when locating a short, a cross, a split pair, or a wet spot.

SECTION IV

MAINTENANCE

	PARAGRAPH
Adjustment of tone unit	13
Care of contacts	14
Renewal of batteries	15

13. Adjustment of Tone Unit

a. Vibrator.

Operate the tone unit switch to position 2 (continuous tone) and adjust the vibrator to operate at as low a frequency as is consistent with obtaining a uniform tone by turning the contact screw and the spring tension screw on the vibrator mounting shown in Figure 14. Take care in making this adjust-

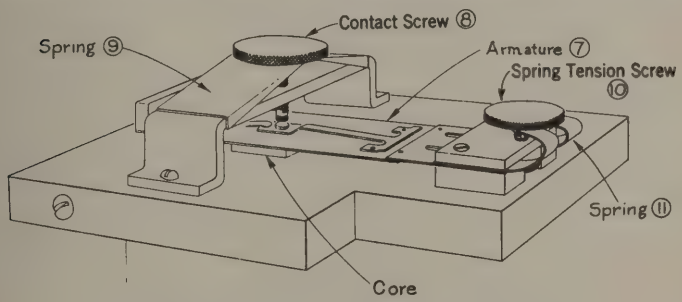


FIGURE 14.—*Tone Unit Vibrator Mounting.*

ment not to turn the contact screw down far enough to stop the vibrator. If the vibrator stops while it is being adjusted, open the switch immediately as the battery circuit is closed through a very low resistance. If this is not done, the battery will run down rapidly. The adjustments should be made so that the armature does not strike the core of the induction coil. The contacts on the armature and the contact screw should be cleaned occasionally by the method described in paragraph 14. To remove the tone unit from the case, press the

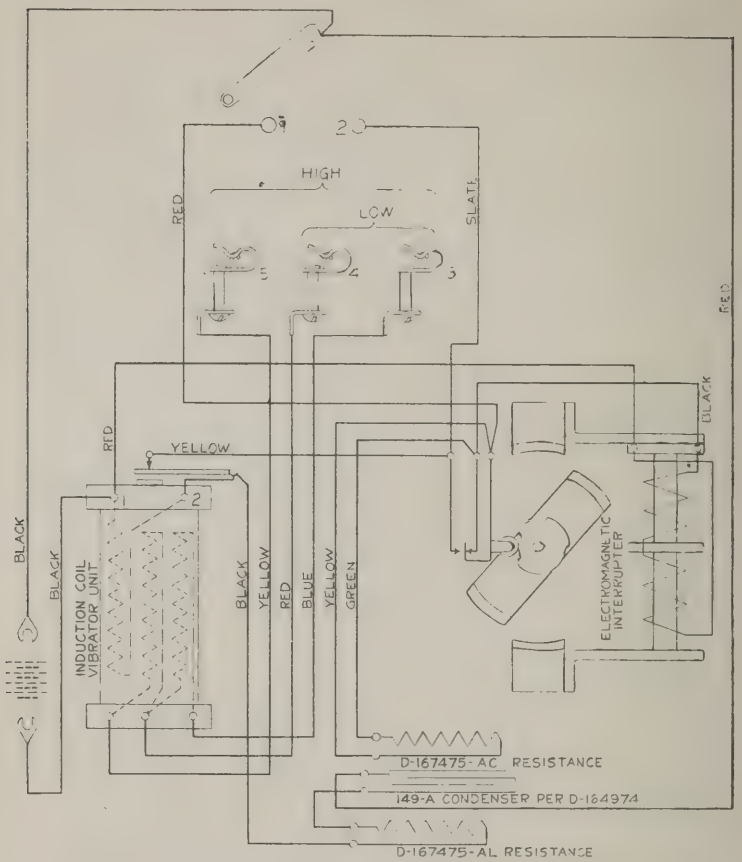


FIGURE 15.—*Tone Unit Wiring Diagram.*

top of the catch springs at the ends of the two compartment covers until the pins which are located in the ends of the compartment covers are disengaged from the springs, when the tone unit may be lifted out of the case. The wiring diagram of the tone unit is shown in Figure 15.

b. Electromagnetic interrupter.

The electromagnetic interrupter, shown diagrammatically in Figure 16, will seldom require adjustment other than occasional cleaning of the contacts on the contact springs and

the operating spring by the method described in paragraph 14. If the interrupter does not function properly after the contacts have been cleaned, adjust it as follows:

(1) Rotate the balance wheel slightly until the roller of the operating spring rests on one of the intermediate working surfaces of the cam; there should then be an air gap of .010 to .015 inch between the contact of the operating spring

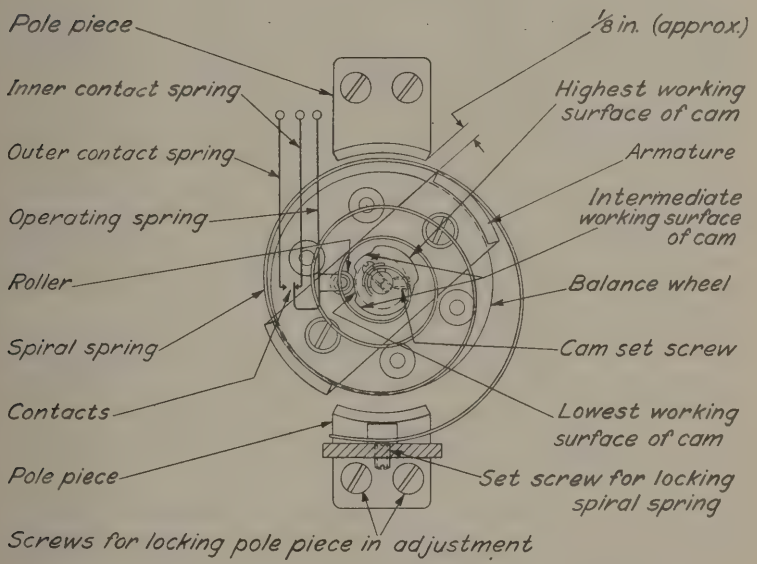


FIGURE 16.—*Electromagnetic Interrupter in Normal Position.*

and that of the outer contact spring and a like air gap between the contact of the operating spring and that of the inner contact spring. If necessary, bend the contact springs and the operating spring slightly to adjust these air gaps.

(2) When the balance wheel is at rest in its normal position, the roller of the operating spring should bear against the lowest working surface of the cam and the operating spring should make positive contact with the inner contact spring. If

necessary, bend the operating spring slightly to meet these conditions.

(3) If the adjustments of subparagraphs 13*b*(1) and (2) have been made correctly, when the balance wheel is rotated until the roller of the operating spring rests on the highest working surface of the cam, the operating spring should make positive contact with the outer contact spring. If necessary, repeat the adjustments described in 13*b*(1) and (2).

(4) Adjust the spiral spring by lengthening or shortening its effective length slightly, as required, to obtain a separation of approximately $\frac{1}{8}$ inch between the armature and the pole pieces, as shown in Figure 16. At the same time adjust the cam to such a position that when the balance wheel is operated manually, it will come to rest with the roller of the operating spring bearing against the lowest working surface of the cam.

(5) Adjust the pole pieces to obtain an air gap of .010 inch to .012 inch between each end of the armature and its respective pole piece.

(6) Lubricate the bearing ends of the balance wheel shaft with a drop of light oil if the need is indicated. Avoid excess oil in the bearings.

14. Care of Contacts

One of the most important points in maintaining contacts is to keep them clean and free from grease or oil and dust. Some contacts, after long periods of service, become worn and pitted. Smooth the contacts with an abrasive, such as a piece of crocus cloth, or very fine emery cloth or sandpaper. Clean out thoroughly any small particles left by these operations. Carbon tetrachloride is satisfactory for this purpose. It should be applied preferably with a clean brush or in some other manner which will not leave particles on the contacts after evaporation of the liquid.

15. Renewal of Batteries

The tone unit is operated by four Batteries BA-23 connected in series. Battery BA-23 has a terminal voltage of

approximately 1.5 volts, which will drop when current is being drawn from the battery. A good indication of the condition of the battery is the amount of drop in voltage after a reasonable period of discharge (one minute). To determine the condition of the batteries in the tone unit and when to replace them, measure the voltage across the four batteries connected in series after a one-minute discharge through a resistance of twenty ohms. Do this while the discharge continues. Replace the batteries when the voltage measured under the above conditions of test drops to 3.7 volts.

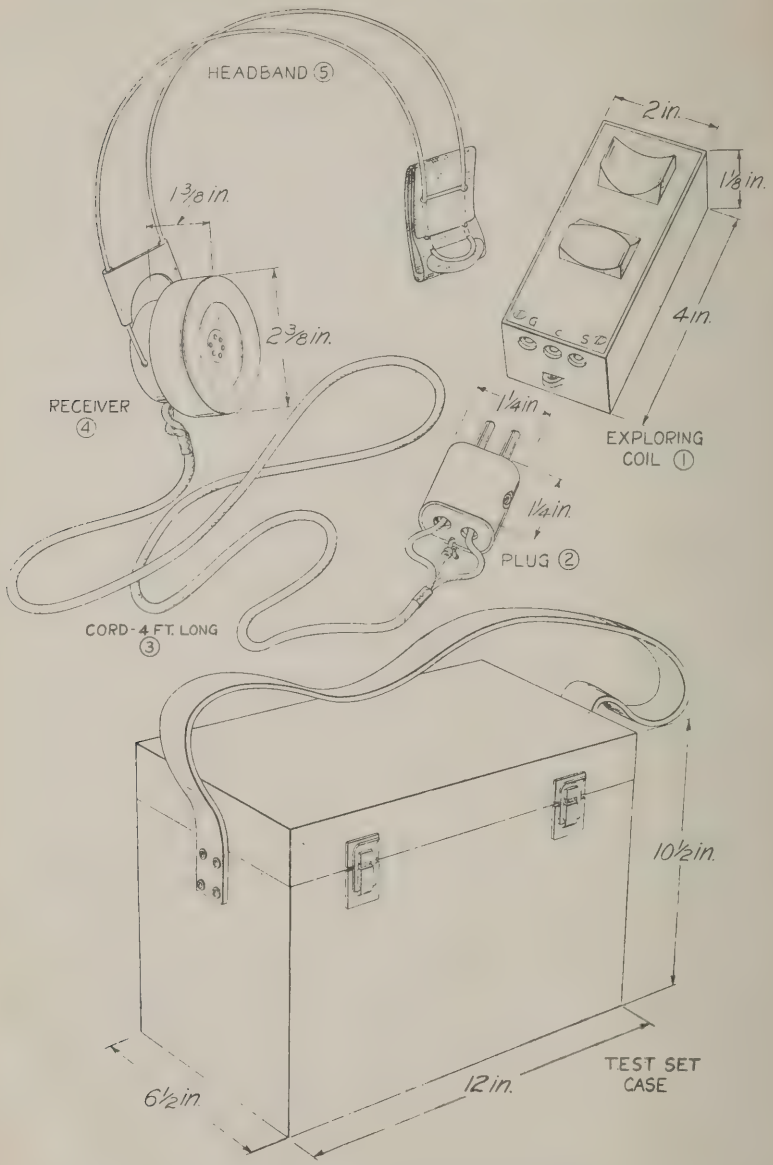


FIGURE 17.—*Outline Dimensional Diagram.*

SECTION V

SUPPLEMENTARY DATA

	PARAGRAPH
Use of auxiliary equipment	16
Table of replaceable parts	17

16. Use of Auxiliary Equipment

a. Wheatstone bridge measurements.

Measurements by means of a Wheatstone bridge (Test Set I-49) may often be used advantageously in conjunction with Test Set I-51. The approximate location of a fault may be determined by means of Varley or Murray loop tests and the exact location can be determined with Test Set I-51. In a great many cases the probable location of the fault may be determined from an inspection of the cable diagram showing the distribution of the conductors involved, after which the fault can be located exactly with Test Set I-51.

b. Use of an amplifier.

Faults, particularly short circuits and split pairs, may be located more readily if an amplifier is used in connection with the exploring coil to amplify the tone picked up from the cable. If an amplifier is employed with the test set, connect the exploring coil to the input side of the amplifier, and connect the output side of the amplifier to the receiver. A Western Electric No. 107-A amplifier or equivalent is satisfactory for this purpose.

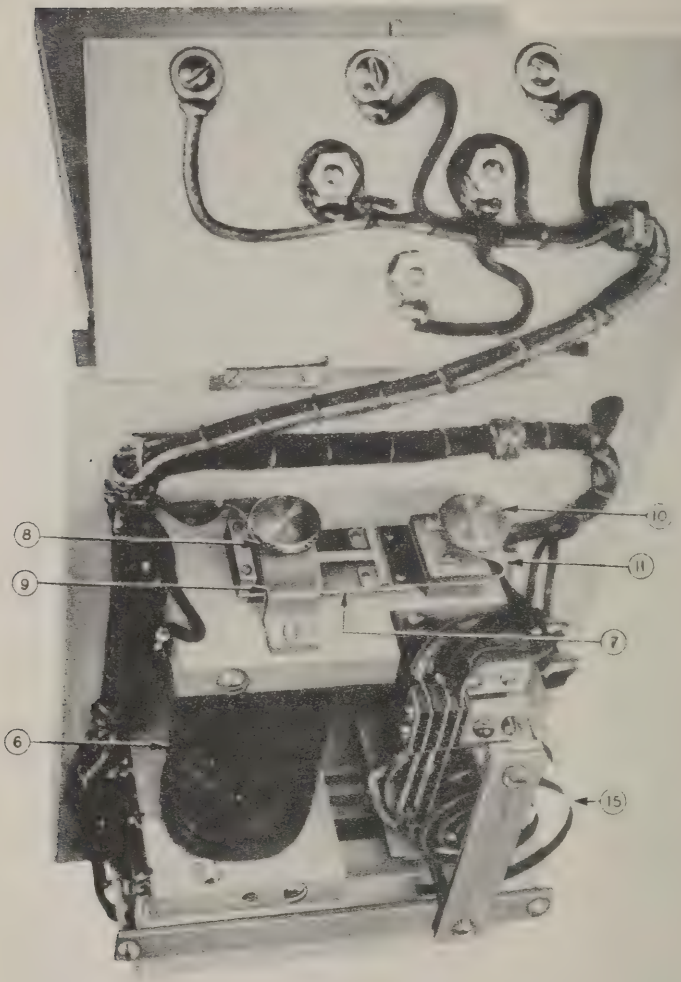


FIGURE 18.—*Tone Unit, Top View.*

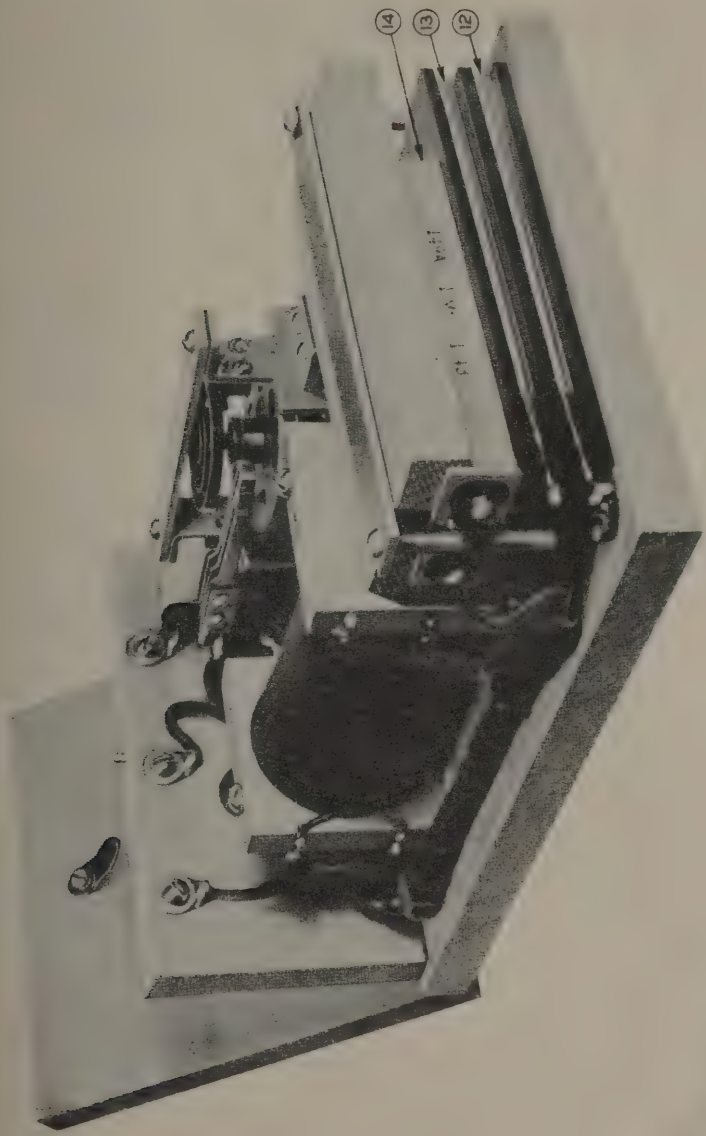


FIGURE 19.—*Tone Unit, Bottom View.*

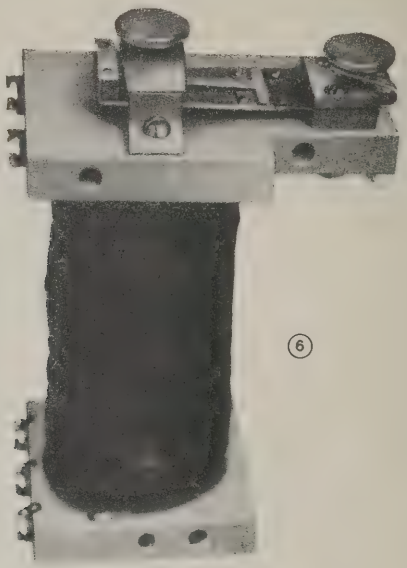


FIGURE 20.—
Induction Coil Vibrator Unit.

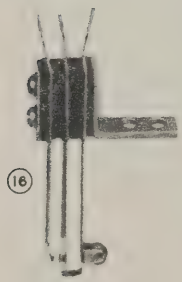


FIGURE 21.—
Spring Assembly.

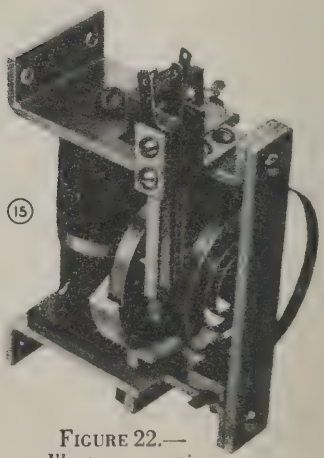


FIGURE 22.—
Electromagnetic Interrupter.

17. Table of Replaceable Parts

Ref. No.	*Stock No.*	*Name of Part*	*Description*	*Function*	*Western Electric Co. Code*
1	3F4051/C1	Exploring coil	Coil (Fig. 17)	To detect electromagnetic fields	19-C Test Set
2	4C7422A.2	Plug	2-conductor plug (Fig. 17)	To connect receiver cord to exploring coil	D-167214
3	3ER2CD	Cord	2-conductor receiver cord (Fig.17)		R2CD
4	4C7592.8	Receiver	Telephone receiver (Fig. 17)	Listening device	716B
5	2B740	Headband	See Figure 17	To support receiver on operator's head	D-142091
6	3F4051/C2	Induction coil vibrator unit	Induction coil and vibrator assembly (Figs. 18 and 20)	To generate alternating voltage	D-167684
7	3F4051/A1	Armature	Vibrator armature (Figs. 14 and 18)		D-167685
8	3Z1710-5	Contact screw	See Figures 14 and 18	To adjust vibrator contact pressure	P-109776
9	3F4051/S2	Spring	See Figures 14 and 18	To lock contact screw	P-109778
10	6L17007-6-1	Spring tension screw	See Figures 14 and 18	To adjust armature spring tension	P-131320
11	3F4051/S1	Spring	See Figures 14 and 18	To lock spring tensioning screw	P-138959

17. Table of Replaceable Parts (Contd.)

Ref. No.	*Stock No.*	*Name of Part*	*Description*	*Function*	*Western Electric Co. Code*
12	3Z6050-100	Resistor	500-ohm resistance (Fig. 19)	To suppress spark across interrupter contacts	D-167475-AC
13	3Z5994-15	Resistor	4-ohm resistance (Fig. 19)	To suppress spark across vibrator contacts	D-167475-AL
14	3DB1.49A	Condenser	1-mf capacitance (Fig. 19)	To suppress spark across vibrator contacts	149-A per D-164974
15	4Z5050	Electromagnetic interrupter	See Figures 16 and 22	To alternately close and open battery circuit	D-167686
16	4Z5050/S5	Spring assembly	See Figure 21	To control operation of interrupter	D-167687
17	3Z1504	Output terminal	Spring clip	To connect circuit under test to tone unit	Fahnestock No. 4 Spring Clip
18	6L6832-11.1	Screw	.166" x 32 R.H.M. Screw 11/16" long	For mounting output terminal (Ref. No. 17)	P-107905
19	6L6836-35.1	Screw	.164" x 36 R.H.M. Screw 2-3/16" long	For mounting resistors (Ref. Nos. 12 and 13) and condenser (Ref. No. 14)	P-138954
20	6L3108-36	Nut	.164" x 36 hex. nut	For mounting resistors (Ref. Nos. 12 and 13) and condenser (Ref. No. 14)	P-138955